Go Deep - Making Stormwater Infiltration Work on Tight Soils

By Dean Young, M.E.S., B.Sc.

For the past twelve years, Dean has worked for the Toronto and Region Conservation Authority (TRCA) in Ontario, Canada. He currently is a Project Manager with the Sustainable Technologies Evaluation Program (STEP) where his work focuses on evaluating the effectiveness of innovative water management technologies in an Ontario context and developing knowledge transfer tools to overcome barriers to widespread implementation. His most recent work focuses on developing guidance on the design and implementation of Low Impact Development (LID) stormwater infrastructure. For more information visit http://sustainabletechnologies.ca.

How effective are stormwater infiltration practices at meeting water balance targets when the development site is on fine-textured, low permeability soil? Are there ways of designing them to maximize drainage performance? Without definitive answers to these questions, designers are left with a much smaller toolkit of Low Impact Development (LID) practices in such contexts, and none that compensate for the loss of groundwater recharge caused by site development. To help answer these questions, evaluations of the performance of several infiltration systems located on glacial till soils in the Greater Toronto Area have been completed. Results prove that they can be effective at meeting groundwater recharge targets on fine-textured soils with thoughtful design.

The Low Impact Development (LID) approach to stormwater management is widely advocated as the best way to manage potential impacts of urbanization on the health of our waterways. Stormwater infiltration practices are an integral part of the LID toolkit, as they help to reduce runoff volume, minimize changes to stream flow, maintain groundwater levels, sustain stream baseflows and reduce pollutant loading to receiving waters. When installed underground as soakaways, infiltration trenches or chamber systems, they also conserve developable land and help create more compact communities.

Despite their advantages, debates continue between stormwater system designers and approvers over the efficacy and acceptability of infiltration practices on sites where native subsoil is fine-textured (i.e. silts and clays). Designers are reluctant to recommend their application on fine-textured soils due to limited permeability and concerns about the size of the facilities that would be needed. Approvers of stormwater management systems want proof that the systems will be effective over the long-term, but they balk when it comes to proposals for pilot testing with uncertain outcomes. Without answers to these questions of efficacy and acceptability, designers are left with a much smaller LID toolkit to work with in such contexts.

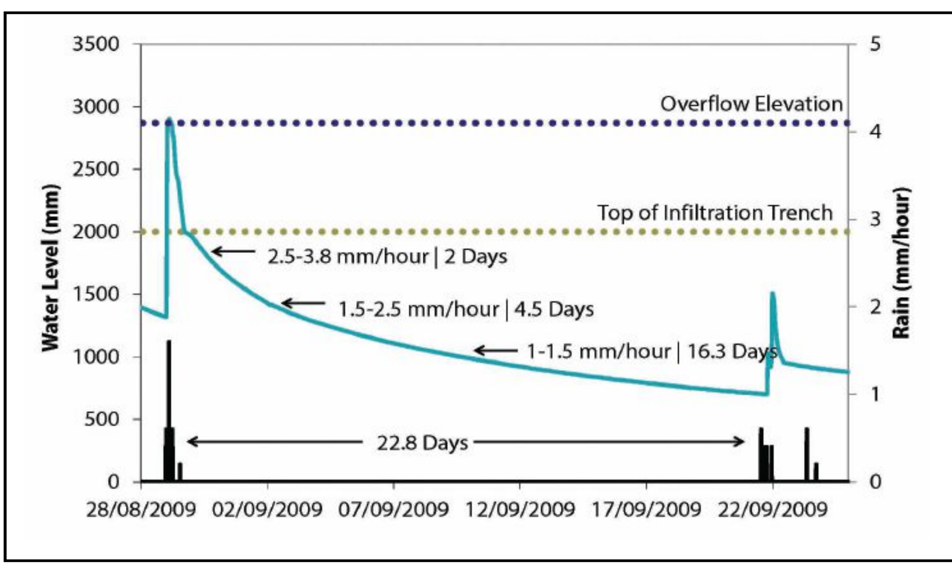


Figure 1: Storm hydrograph of a two metre deep infiltration trench located on clayey silt till soil showing exponential decline in drainage rate as water level in the practice declines.

A stormwater infiltration chamber system being installed on silty to clayey glacial till soil that is common in the Greater Toronto bioregion.

STEPs To End the Debate

In areas like Southern Ontario, where the majority of urban growth is occurring on fine-textured soils, there is considerable interest in understanding how effective infiltration systems can be and how to design them to maximize drainage performance. To help answer these questions, field monitoring evaluations of the effectiveness of a variety of infiltration practices located on fine-textured glacial till soils in the Greater Toronto Area have been completed by the Sustainable Technologies Evaluation Program (STEP) of the Toronto and Region Conservation Authority.

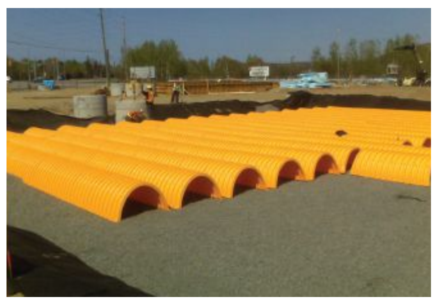
STEP was introduced in 2004 to foster broader implementation of clean water and energy technologies in Ontario by generating information on their performance and cost-effectiveness derived from local field evaluations and disseminating guidance on their design, lifecycle costs, inspection and maintenance (www.sustainabletechnologies.ca).

Drainage performance of permeable pavements, bioretention cells, infiltration trenches and chamber systems, all located on glacial till soils, have been examined through continuous monitoring of rainfall depth, outflow and water level in the practices, typically over two to three year monitoring periods. While drainage rates of infiltration sumps (i.e. water storage reservoirs below sub-drain outlets) are definitely slow, in the order of 2 to 5 mm/h over the first 48 hours after being filled to capacity, substantial reductions in runoff volume can be achieved with thoughtful design.

For example, an infiltration chamber system receiving roof drainage from two big box commercial developments and installed on sandy silt glacial till soil (40 percent sand; 35 percent silt; 25 percent clay) in Richmond Hill, Ontario was found to reduce runoff by 90 percent and maintain pre-development annual infiltration volume over the lot.[3] Such impressive performance is due to the large water storage capacity of the system, which is capable of storing runoff from a 41 mm rainfall event over the roof drainage area.

Other evaluations of the drainage performance of permeable pavements and bioretention cells located on silty clay glacial till soil and featuring sub-drains have shown they can reduce runoff volume in the order of 43 to 90 percent with the addition of flow restrictors that extend drainage time from 24 hour to 36 hours.[1, 2]

In terms of how best to design infiltration practices on fine-textured soils, some key insights came from examining the drainage performance of a series of four underground, rectangular infiltration trenches, two metres in depth each. In this case, the trenches are located on clayey silt till soil (1 percent sand; 57 percent silt; 42 percent clay) and receive roof drainage from large commercial buildings (1.4 to 5.8 hectare roof areas).



Underground infiltration systems can be effective on fine-textured soils at maintaining pre-development groundwater recharge with thoughtful design.

An important observation was that trench drainage rates decline exponentially as water levels decline (Figure 1) and are about 2.5 times higher when full than when half full of water. By the time that water level in the gravel-filled trench is below one metre in depth, drainage is occurring very slowly (< 1 mm/h), suggesting that infiltration practices with shallow water storage reservoirs will not drain well on such tight soils.

This finding also suggests that to increase drainage performance in such contexts, they should be designed to maintain hydraulic head in the water storage reservoir for longer than the typical target of 48 to 72 hours. This design would help maximize the drainage rate and therefore increase the volume of water infiltrated on an annual basis. On low permeability soils, this means designing systems that may never fully drain between storm events; so details, like sealable manholes with no holes, may be needed to avoid creating mosquito breeding habitat.

A key conclusion from this work is that for developments on fine-textured soils, where roof area makes up at least 50 percent of the lot, underground infiltration practices can fully compensate for the loss of groundwater recharge caused by site development through infiltration of roof runoff alone. This finding is significant, considering that such practices are widely thought to have limited effect in these contexts. Considering that, in most cases, roof runoff is a relatively clean source of stormwater, directing it to underground infiltration practices is a low risk and low maintenance approach for meeting groundwater recharge targets.

Learn More in Portland

It is time to end the debate over whether or not infiltration practices will work on fine-textured soils and to get on with the business of designing and accepting them, with realistic expectations of their performance.

If you like what you just read and are interested in learning more about this topic, consider attending the Environmental Connection 2015 conference in Portland, Oregon. Dean will be presenting on the performance and design of infiltration practices on low permeability soils on February 16 and 18, 2015.

For development sites where roof area makes up half of the lot or more, groundwater recharge targets can be met through infiltration of roof runoff alone.

References

1. Drake, J., Bradford, A., Van Seters, T. 2012. "Evaluation of Permeable Pavements in Cold Climates - Kortright Centre, Vaughan." Toronto and Region Conservation Authority. Toronto, Ontario.

2. Van Seters, T. and Graham, C. 2014. "Evaluation of a Bioretention System - Earth Rangers, Vaughan." Toronto and Region Conservation's Sustainable Technologies Evaluation Program, Toronto, Ontario.

3. Young, D. Van Seters, T., Graham, C. 2013. "Evaluation of Underground Stormwater Infiltration Systems." Toronto and Region Conservation Authority. Toronto, Ontario.

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